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Observations

of the

OWENS VALLEY RADIO OBSERVATORY

California Institute of Technology

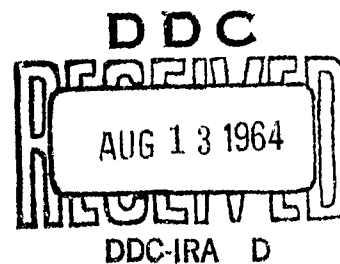
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7. DECIMETER MEASUREMENTS
RELATING TO THE POSSIBLE DISPLACEMENT
OF JUPITER'S MAGNETIC DIPOLE

by

G. L. Berge and D. Morris



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During the period 29 October to 4 November, 1963, the planet Jupiter was observed using the interference polarimeter of the Owens Valley Radio Observatory at a wavelength of 10.4 cm and an east-west separation of 800 feet or 2350λ . Each of the two 90-ft paraboloids of the interferometer was equipped with a rotating feed horn. The observations were part of a brightness distribution study of Jupiter and consisted of repetitious measurements made with four successive horn orientations. The theory of this procedure and the result in terms of Stokes parameters are discussed by Morris, Radhakrishnan and Seielstad (1964). In the case of Jupiter, the plane of polarization is always roughly parallel to Jupiter's equator. For the purposes of this communication only two of the horn orientations are of interest: both horns parallel with the E-vector parallel to Jupiter's axis (sensitive only to the non-polarized radiation) and horns crossed, 45° on each side of the equatorial direction (sensitive only to the polarized radiation). The amount of time devoted to the observations ranged from four to eight hours each night. A mechanical integrator, similar to that described by Morris, Clark and Wilson (1963) was used to determine the fringe amplitudes and relative fringe phases of the measurements as a function of hour angle. All observations were normalized to correspond to a distance for Jupiter of 4.0412 A.U. At the time there was a 25° tilt of Jupiter's equator with respect to the resolution direction of the interferometer. This direction was not a function of hour angle because the declination of Jupiter was nearly 0° .

The off-transit measurements with the parallel horn arrangement just described showed that the non-thermal, non-polarized portion of the radiation reached the first null of its visibility function at an effective baseline of about 1860λ . This assumes that there was a thermal contribution of 1.3 flux units from the planetary disk, which was unresolved. Hence, at a baseline of 1860λ , only the thermal component was seen. Meanwhile, similar measurements using the crossed horn arrangement showed that the plane-polarized portion was resolved at about 1250λ and was well up on a rather shallow second maximum at 1860λ and beyond. Under these conditions, the apparent east-west position of the polarized emission of the planet with respect to the thermal emission of the planetary disk is proportional to the difference in phase of the interference fringes of the crossed horn measurement and the parallel horn measurement.

Figure 1 displays the phase of the polarized radiation (crossed horns) minus the phase of the thermal radiation (parallel horns)

plotted as a function of λ_{III} . There is also a scale which shows what this means in units of equatorial radii. All of the points are within two hours of transit and each has been corrected for baseline foreshortening by normalizing to the transit baseline. Because the observations were not made at exactly 1860λ , the parallel horn measurements have also been corrected for the non-thermal contribution (up to 30%) included in them, assuming that it has the same phase as the polarized radiation.

If the polarized radiation were symmetric with respect to the planetary disk, we would expect Figure 1 to be a straight line along 180° because the polarized part is on the second maximum of its visibility function and thus has changed its phase by 180° . Instead, we find a variation periodic in λ_{III} which is superimposed on a constant shift to the west. In addition it appears that the periodic term may not be sinusoidal.

It is natural to suppose that the effect we observe for the polarized radiation is true for the non-thermal emission in general. The most direct explanation for the result is that there is a physical displacement of the emitting region due to a displacement of the magnetic dipole from the center of the planet. The periodic term can be explained by a shift away from the rotational axis along the meridian plane at longitude 130° or 140° . The constant term can be explained by a northward shift parallel to the rotational axis. At the time of the observations, the position angle of the axis was 335° so that such a shift along the axis would result in a constant component to the west in celestial coordinates.

If this is the correct interpretation, then shading by the planet creates an additional effect which has not been corrected for. In general the shading will exaggerate the variable term so that it appears larger than it should. For example, if the polarized emission originated in two equal east-west strip sources three equatorial diameters long, with one behind and one in front of Jupiter's disk, then the displacement would be exaggerated by 20%. The apparent departure from a sinusoid can probably be explained by a more subtle shading effect. A correction for shading cannot be made without a detailed picture of the brightness distribution, and this is not yet available. Fortunately, Figure 1 is based on the polarized emission which has very large equatorial dimensions, and hence it should not be seriously affected by shading.

Warwick (1963) has already proposed a large dipole displacement to account for the main features of the dynamic spectrum of the decimeter emission. He supposed that electrons precipitating from a radiation belt produce Cerenkov emission at nearly the gyrofrequency. The radiation is sharply beamed along the field lines. It reflects from the ionosphere or planetary surface by the usual reflection condition and is still sharply beamed. The magnetic dipole is displaced to provide a slowly varying magnetic field along the strip where electrons could be dumped from the radiation belt, and this in turn will account for the slow frequency drifts in the dynamic decimeter spectrum. By comparing synthetic spectra for a variety of displacements with the observations, Warwick determined what the dis-

placement should be according to this theory and found that only the northern auroral zone was involved.

The coordinate system used by Warwick is as follows: the polar axis is the z-axis with north positive. Jupiter's center is the origin and the xz-plane is the meridian plane at $\lambda_{III} = 200^\circ$ with the x-axis directed away from the center at that longitude. The xz-plane was chosen in this way because the dipole is tipped with respect to the polar axis and its direction is parallel to the meridian plane at roughly 200° longitude (Morris and Berge 1962). The upper end is tipped toward the earth at LCM = 200° . In this system the displacement found by Warwick was $(x_N, y_N, z_N) = (+0.15, +0.11, -0.73)$ in equatorial radii. The displacement which we find from Figure 1 after allowing for the tilt of the polar axis away from celestial north is about $(+0.2, +0.4, +0.5)$. Notice that both displacements are in the same azimuthal quadrant, but in different octants.

We have constructed a synthetic dynamic decameter spectrum in the manner of Warwick (1963) in which we have substituted our position for the dipole. In this case only the southern auroral zone is involved. As one may expect, the result of these calculations does not agree with observation. In particular, between $\lambda_{III} = 160^\circ$ and 360° there is no emission beamed toward the earth according to the synthetic spectrum. However, we have noticed that if, instead of reflecting from Jupiter's ionosphere, the radiation originally propagates outwards along field lines (Chang 1963), then a reasonable synthetic spectrum can be obtained. There is an "early", positive drift source and a "late", negative drift source. This spectrum may correspond to the distinctive upper frequency boundary which Warwick's observations seem to indicate. In this case the lower frequency radiation at a given longitude could originate further out on the same field lines and away from the planet.

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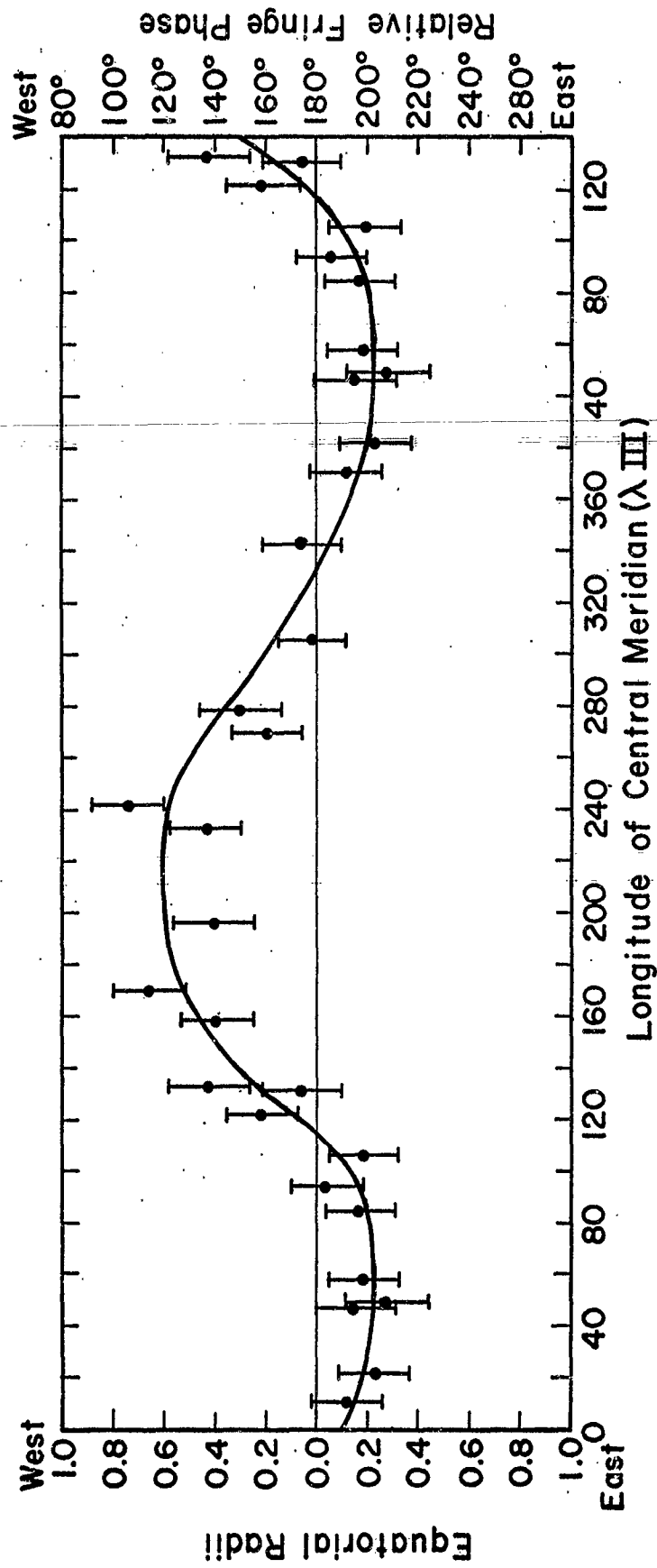


Figure 1. The east-west position of the polarized emission of Jupiter with respect to the thermal emission as a function of longitude of the central meridian (System III).